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STATUS REVIEW AND TAXONOMIC STUDIES
OF Astragalus molybdenus

U.S.D.A. FOREST SERVICE - REGION 1
LEWIS AND CLARK NATIONAL FOREST

MONTANA

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ACKNOWLEDGMENTS

These studies were funded under a challenge cost-share agreement between the Montana Natural Heritage Program and the U.S. Forest Service, Lewis & Clark National Forest. We thank Wayne Phillips and Dr. Angela Evenden for their support and interest. We gratefully acknowledge the technical support from Dr. Matt Lavin and Sarah Mathews, Montana State University (chloroplast DNA analysis), and Dr. Greg Brown, University of Wyoming (isozyme electrophoresis); their work provided valuable information on taxonomic relationships among the study populations. Hollis Marriott, Wyoming Natural Diversity Data Base, provided invaluable information on populations in Wyoming and Colorado, and collected plant specimens from those states. Rupert Barneby, New York Botanical Garden, examined collections from all three states, and shared his valuable perceptions regarding the two species. Dr. Angela Evenden and John Pierce (U.S. Forest Service, Missoula, Montana) assisted with the field surveys and sample collections in Montana; their help and companionship was invaluable to the success of this work.

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I. INTRODUCTION

SCIENTIFIC NAME: Astragalus molybdenus Barneby.

COMMON NAME: Leadville milk-vetch.

FAMILY: Fabaceae (= Leguminosae; Pea Family).

The first known collection of Astragalus molybdenus was made in 1873, in the Park Range of Colorado (Barneby 1964). Barneby (1949) initially named the species A. plumbeus. However, since this name had already been applied to a different species in Russia, he subsequently renamed it A. molybdenus (Barneby 1950). Within the genus, A. molybdenus was placed in the Phacoid group, in section Minerales. The Phacoid group is thought to be the most primitive one within the genus. The chromosome number for A. molybdenus remains unknown. Once this information is obtained, it may suggest that its affinities lie elsewhere in the genus (Barneby 1964).

For many years, A. molybdenus was known only from alpine areas near Leadville and Aspen, Colorado. In 1982, an Astragalus specimen was collected, in flower, on Mount Wright, Teton County, Montana (Lackschewitz et al 1984). Although the specimen lacked ripe pods, Rupert Barneby (New York Botanical Garden) identified it as Astragalus molybdenus; he felt it was different from collections of A. shultziorum, a very closely related species recently described (Barneby 1981) from western Wyoming (Klaus Lackschewitz, pers. comm.). This station on Mount Wright represented a disjunction of approximately 960 km (600 mi) northward from the A. molybdenus populations in Colorado. Thus, the range was divided, with A. shultziorum occurring between the Montana and Colorado locations of A. molybdenus.

Owing to the overall morphological similarities between A. molybdenus and A. shultziorum, the specific status of the latter has been questioned. Dorn (1988) treated A. shultziorum as a synonym of A. molybdenus. Thus, in 1989, the Montana Natural Heritage Program and the Wyoming Natural Diversity Database initiated status survey projects that included an assessment of the taxonomic relationship of these species. The Lewis and Clark National Forest and the Montana Natural Heritage Program established a challenge cost-share agreement. The goals of this project were: 1.) to study the distribution of A. molybdenus populations on the Forest, 2.) to collect specimens that would allow more detailed comparison of the Montana and Colorado populations with those of A. shultziorum from Wyoming, and 3.) to collect leaf samples for use in molecular systematic studies. It was hoped that the taxonomic status of the

populations in all three states could then be more clearly defined.

II. METHODS

This project consisted of two parts: 1) field surveys to determine the distribution, abundance, and habitat of Astragalus molybdenus in Montana, and to assess threats to the populations; and 2) a taxonomic study to determine the relationship between A. shultziorum populations in Wyoming, and A. molybdenus populations in Colorado and Montana.

A. SURVEY

In Montana, the known site on Mt. Wright was relocated and fully mapped. Additional searches were conducted in potential habitat on peaks and ridges to the south of Mt. Wright. These surveys were completed on 7-10 and 21-23 August 1989. The distribution information obtained from these surveys is found in Section III. C., pp. 5 and in the maps and occurrence records in Section VI, pp. 25-37. Information obtained on management needs and the biology of this species are reported under the respective sections in the body of this report.

B. TAXONOMIC STUDIES

A variety of approaches were used to assess the taxonomic relationships among the Montana and Colorado populations of A. molybdenus, and the Wyoming populations of A. shultziorum. Plant leaf material was collected from five Montana populations by the authors, and from three sites in Colorado, and six sites in Wyoming, by Hollis Marriott (Wyoming Natural Diversity Data Base (WNDDDB). Leaf material was provided to Dr. Matt Lavin, Montana State University, for chloroplast DNA (cpDNA) analysis, and to Dr. Greg Brown, University of Wyoming, for isozyme electrophoretic studies. Additionally, full collections were sent to Rupert Barneby of the New York Botanical Garden, an expert on the genus Astragalus. Results of the taxonomic studies are given in Section III. F., pp. 12-19.

III. SPECIES INFORMATION

A. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL STATUS

- a. U.S. FISH AND WILDLIFE SERVICE: None.

- b. U.S. FOREST SERVICE: Astragalus molybdenus is currently included on the U.S. Forest Service list of sensitive species for Region 1 (U.S. Department of Agriculture 1988). Objectives and policy of the U.S. Forest Service provide for the management and protection of sensitive species under sections 2670.22 and 2670.32 in the 1984 Forest Service Manual. Under these guidelines, the Forest Service is to (a) "maintain viable populations of all native species of plants" (2670.22), and (b) "avoid or minimize impacts to species whose viability has been identified as a concern" (2670.32.3).
2. STATE: Astragalus molybdenus has been listed as "rare" by the Montana Rare Plant Project (Lesica et al. 1984). This category includes "those species which are limited to a restricted geographic range...in Montana." Globally, Astragalus molybdenus is currently listed by the Montana Natural Heritage Program (Shelly 1990) as "very rare" (21-100 occurrences; global rank = G3). It is listed as "critically imperiled in Montana because of extreme rarity" (state rank = S1). These ranks do not currently provide any direct legal protection for A. molybdenus.

B. DESCRIPTION

1. GENERAL NONTECHNICAL DESCRIPTION: A member of the Pea Family (Fabaceae), Astragalus molybdenus is a low-growing, loosely matted plant, with prostrate to upright stems. Leaves are borne alternately along the stems, and each compound leaf consists of 9-25 oval leaflets. Plants may bear 1-6 small (0.5 inch) purple, or occasionally whitish, pea-type flowers. Fused green sepals (outer floral leaves) surround each flower, and are covered with long, black hairs. The fruit is a small, pendulous, curved pod (adapted from Reel et al. 1989). See Section VII, pp. 38-46, for color photos of plants and habitat.
2. TECHNICAL DESCRIPTION: Low, loosely tufted or matted perennial, with a slender taproot and loosely, sometimes extensively branching subterranean stems persisting as rhizome-like caudex-branches (sometimes adventitiously rooting and thus vegetatively reproductive), the stems with fine, nearly straight, appressed and

ascending hairs up to 0.4-0.5 mm. long, greenish-cinereous to silvery-gray, the leaflets sometimes medially glabrescent above, the inflorescence black-hairy; stems of the season largely subterranean, the aerial tips prostrate or weakly ascending, 0.5-6 (14) cm. long, the internodes all short, or a few of them developed and up to 1.5 (4) cm. long, mostly shorter; stipules 2-5 mm. long, submembranous, purplish, glabrous dorsally, the lowest becoming pallid and scarious, all amplexicaul and connate through \pm half their length, the free blades deltoid or lanceolate, obtuse or subacute; leaves 1.5-7 cm. long, petioled, with (9) 17-25 ovate, ovate-oblong, or elliptic, obtuse, mostly crowded, folded or involute leaflets 2-10 mm. long; peduncles at anthesis incurved-ascending, procumbent in fruit, 1-3 (6.5) cm. long; racemes loosely 3-6 flowered, the flowers loosely ascending, the axis scarcely elongating, 3-10 (15) mm. long in fruit; bracts membranous, lanceolate, ovate-acuminate, 2.5-5 mm. long; pedicels at anthesis 0.5-1.5 mm. long, in fruit either straight or arched outward, 1-2 mm. long; bracteoles 0-2, minute when present; calyx 5.2-7 mm. long, densely black-strigulose, the oblique disc 0.5-0.8 mm. deep, the campanulate tube 3-4.2 mm. long, 2.7-3.2 mm. in diameter, the broadly subulate teeth 2-3 mm. long; petals pink-purple, dull lilac, or whitish with banner veined and distally suffused with lilac, the keel-tip always maculate; banner recurved through \pm 45 degrees, ovate-cuneate, notched, 10.7-12.5 mm. long, 5.2-7.2 mm. wide; wings 9.3-10.9 mm. long, the claws 3.3-4.4 mm., the oblong-obovate, obtuse, slightly incurved blades 6.6-8 mm. long, 2.5-2.7 mm. wide; keel 8.8-9.7 mm. long, the claws 3.8-4.7 mm., the broadly lunate blades 5.3-5.7 mm. long, 2.3-2.8 mm. wide, incurved through 90-100 degrees to the bluntly triangular apex; anthers 0.45-0.6 mm. long; pod ascending (humistrate), sessile or nearly so, obliquely ovoid or ovoid-ellipsoid, a trifle incurved, 7-11 mm. long, \pm 3.5 mm. in diameter, rounded at base, abruptly deltoid-beaked and cuspidate at apex, subtriquetrously compressed with acute ventral and rounded lateral angles, flattened or somewhat depressed dorsally but hardly sulcate, the prominent ventral suture either straight or a trifle concave in profile, the thin submembranous, densely black- or more rarely partly white-strigulose valves not inflexed; dehiscence not seen; seeds (not seen

quite ripe) \pm 4.2-4.5 mm. long (adapted from Barneby 1964).

3. LOCAL FIELD CHARACTERS: Astragalus molybdenus is only positively identified in fruit. It is distinguished from other co-occurring Astragalus species by its small, distinctly three-angled (making it appear slightly inflated), curved fruits, and leaflets, which have hairs only along their margins and dorsal surfaces.

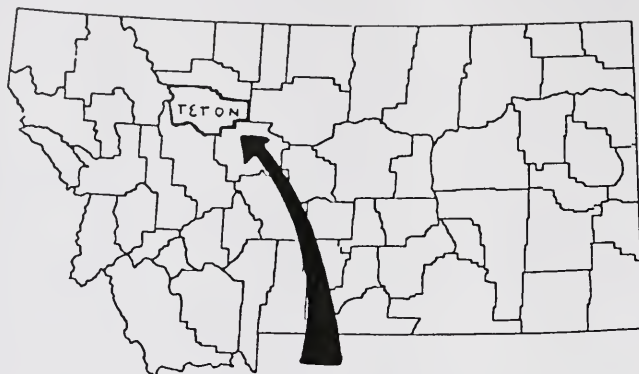
Vegetatively, Astragalus molybdenus is similar to, and co-occurs (in Montana) with, A. bourgovii, A. alpinus, and A. vexilliflexus. Fruits of A. vexilliflexus are curved, and resemble those of A. molybdenus, but are not three-angled (appearing flat in side view). The fruits of A. bourgovii and A. alpinus are only gently curved, and not distinctly three-angled.

Other useful (but not definitive) characteristics in the vegetative state include the yellow-green stems of A. molybdenus (A. vexilliflexus has distinctly reddish stems), and the presence of minute hairs only along the margins and dorsal side of the leaflets (A. bourgovii and A. alpinus both have minute hairs that extend onto the adaxial side of the leaflets).

C. GEOGRAPHICAL DISTRIBUTION

1. RANGE: In Montana, A. molybdenus is currently known from eight populations in the Sawtooth Range, Teton County, near the headwaters of the North and South Forks of the Teton River. The locations are included in Figure 1, p. 6. These populations occur within 10 air miles of one another (U.S.G.S. 7.5' topographic maps: Our Lake and Mt. Wright). The Montana populations are disjunct from populations in Colorado by nearly 960 km (600 mi). Limestone substrates are common in the Sawtooth Range, and extensive areas of potential habitat exist for some miles to the north and south of these populations. There was not enough time to thoroughly survey all the potential habitat for this species.

The distribution of population centers of Astragalus molybdenus in Montana and Colorado, and A. shultziorum in Wyoming, is shown in Figure 2, p 7.



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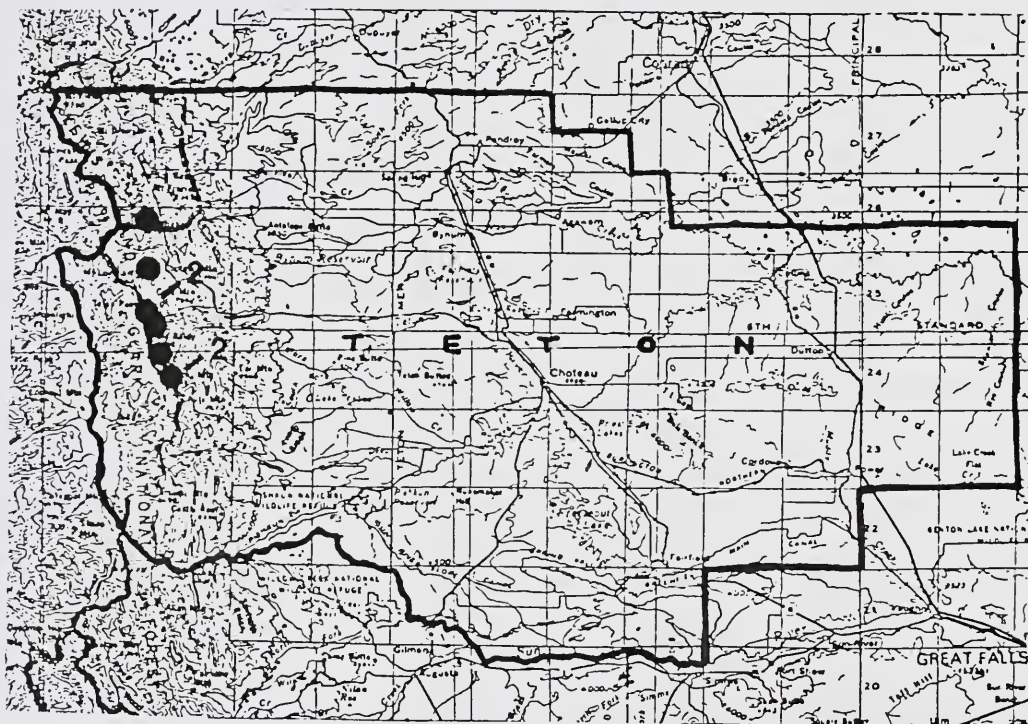


Figure 1. Locations of the eight Astragalus molybdenus populations in the Sawtooth Range, Teton County, Montana. Numbers next to dots indicate the presence of multiple populations in close proximity.

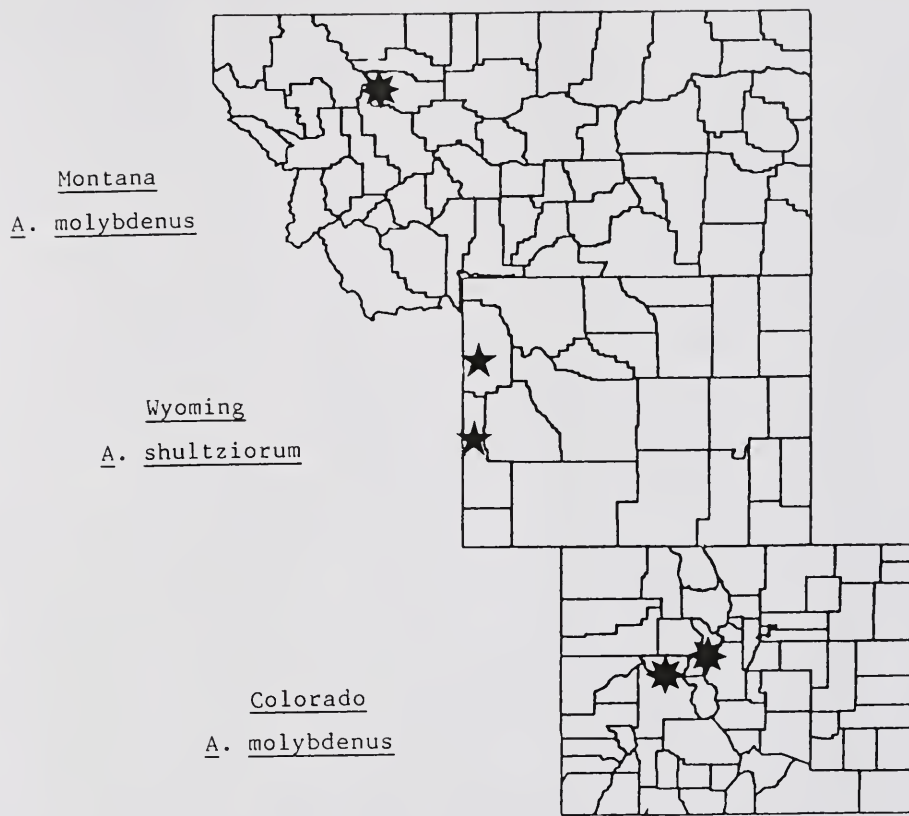


Figure 2.

- ★ - indicate locations of population centers of Astragalus molybdenus in Montana and Colorado.
- ★ - indicate locations of population centers of Astragalus shultziorum in Wyoming.

2. CURRENT SITES: In 1989, field surveys of a portion of the Sawtooth Range in Montana revealed seven new populations of A. molybdenus. This brings the total number of currently documented populations in Montana to eight, all occurring in Teton County. All of the populations occur on lands managed by the U.S. Forest Service, Lewis and Clark National Forest. Four of the populations occur on the border of the Bob Marshall Wilderness (Our Lake (002), Rocky Mountain-West (004), Rocky Mountain-Northeast (005), and Route Creek Pass (006)).

The legal descriptions, elevations, USGS topographic map names, and locations of sites in Montana are provided in Section VI, pp. 25-33. Also, the exact locations are indicated on the maps provided in Section VI, pp. 34-37.

3. HISTORICAL SITES: None known.

4. UNVERIFIED/UNDOCUMENTED REPORTS: None known.

D. HABITAT

1. ASSOCIATED VEGETATION: In Montana, A. molybdenus occurs primarily as a member of alpine forb communities. Populations also occur in the subalpine, but only on very exposed sites, where the microclimate is probably more similar to alpine habitats. Plants were most often observed growing in dense mats of Dryas octopetala, but were also seen spreading in open scree. Plant species that co-occur with A. molybdenus at one or more of the sites include:

<u>Androsace chamaejasme</u>	sweet-flowered androsace
<u>Anemone cylindrica</u>	candle anemone
<u>Antennaria aromatica</u>	aromatic pussy-toes
<u>Aquilegia jonesii</u>	limestone columbine
<u>Arctostaphylos uva-ursi</u> ...	kinnikinnick
<u>Astragalus alpinus</u>	alpine milk-vetch
<u>Astragalus bourgovii</u>	Bourgeau's milk-vetch
<u>Astragalus vexilliflexus</u> ..	bent-flowered milk-vetch
<u>Bupleurum americanum</u>	American thorough-wax
<u>Campanula rotundifolia</u>	lady's thimble
<u>Cerastium arvense</u>	field chickweed
<u>Claytonia megarhiza</u>	alpine springbeauty
<u>Douglasia montana</u>	Rocky Mountain douglasia
<u>Dryas octopetala</u>	white dryas
<u>Erigeron compositus</u>	cut-leaved daisy
<u>Erigeron lackschewitzii</u> ...	Front Mountain erigeron

<u>Hedysarum sulphurescens</u> ...	sulphur hedysarum
<u>Juniperus communis</u>	common juniper
<u>Kobresia bellardii</u>	Bellard's alpinesedge
<u>Oxytropis podocarpa</u>	stalked-pod crazyweed
<u>Oxytropis viscida</u>	sticky locoweed
<u>Poa grayana</u>	Gray's bluegrass
<u>Polemonium pulcherrimum</u> ...	skunk-leaved polemonium
<u>Potentilla fruticosa</u>	shrubby cinquefoil
<u>Potentilla diversifolia</u> ...	diverse-leaved cinquefoil
<u>Salix nivalis</u>	snow willow
<u>Saxifraga bronchialis</u>	spotted saxifrage
<u>Sibbaldia procumbens</u>	creeping sibbaldia
<u>Smelowskia calycina</u>	alpine smelowskia
<u>Zigadenus elegans</u>	glaucous zigadenus

Of these, Oxytropis podocarpa and Erigeron lackschewitzii are included on the U.S. Forest Service, Region 1, sensitive plant and watch lists, respectively.

2. TOPOGRAPHY: In Montana, populations of A. molybdenus occur at or above the krummholz zone in areas where snow deposition occurs. These sites range from nearly level, to steep slopes (0-35%). Most sites in Montana have a north or northwest aspect; however, populations do occur on south- or east-facing slopes. The sites range from 7,263 to 8,120 feet in elevation.

In Colorado, recently surveyed A. molybdenus populations occur from 11,900 to 12,500 feet in elevation; it has been collected as high as 13,000 feet. As in Montana, these locations are above treeline, in alpine forb communities (Tamara Naumann, pers. comm.).

In Wyoming, A. shultziorum occurs at elevations from 8,800 to 10,500 feet, with most habitat occurring between 9,000 and 10,000 feet. Astragalus shultziorum appears to be restricted to subalpine sites, only occasionally reaching into the lowermost alpine zone (Marriott 1990).

3. SOIL RELATIONSHIPS: The Montana populations of A. molybdenus appear to be restricted to largely stabilized, limestone scree slopes. This scree is derived from limestone parent material of Mississippian or Devonian origin (Mudge et al. 1983). However, populations occasionally occur where scree is unstable, as at Our Lake (002). Populations were more often found in alpine forb communities, especially in Dryas octopetala mats.

These mats appeared to be the principal soil stabilizer in these habitats.

In Wyoming, A. shultziorum is almost always found in calcareous habitats. Populations occur in soils derived from the Triassic Thaynes limestone and the Paleozoic Wells and Amsden Formations in the Salt River Range. In the upper Spring Creek drainage, A. shultziorum is occasionally found on a fine red soil that may not be calcareous. In the Teton Range, it occurs on several Paleozoic limestones and dolomites, including the Darby, Bighorn, Gallatin and Gros Ventre Formations. Astragalus shultziorum is commonly found on somewhat vegetated rocky soils. In the Salt River Range, it is often a co-dominant on vegetated talus or scree at the bases of slopes below calcareous cliffs. In the Teton Range, populations are especially well-developed on fine soils with calcareous pebbles, apparently derived from the Death Canyon member of the Cambrian Gros Ventre Formation. At these locations it almost always grows in open habitat, usually in subalpine forb communities (Marriott 1990).

4. REGIONAL CLIMATE: The Sawtooth Range is commonly referred to as the "Front Range" of north-central Montana. It is generally dominated by dry, continental weather conditions. Much of the yearly precipitation falls as rain or wet snow in May and June, with large convective storms providing the mid- and late summer moisture. Winters are cold, dry, and windy, with precipitation occurring mostly in the form of snow. For the Sawtooth Range populations, the nearest long term climatological station is at Gibson Dam (4,736 ft), located approximately 14 air miles south and approximately 3,300 feet lower than the plant populations. The mean annual temperature for the time period 1951-1980 was 41.7° F. The mean maximum temperature for July was 77.9° F, while the mean minimum temperature for January was 11.2° F. For every 1,000 feet in elevation gain, there is an estimated 5° drop in temperature. Thus, the averages given above are likely to be 10-15° higher than the actual temperatures that the plant populations experience. Mean annual precipitation was 18.52 inches (U.S. Department of Commerce 1982).

Populations of A. shultziorum and A. molybdenus from Wyoming and Colorado, respectively, also incur a similar continental climate.

E. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: In Montana, A. molybdenus flowers and fruits from late July through August, depending on climatic conditions and slope aspect. In 1989 large numbers of stems in nearly all of the Montana populations were vegetative. Flowering and fruiting was restricted to very small portions of the populations during that year; the exception was Our Lake (002). In 1990, flowering and fruiting at Our Lake (002) was again high, although it appeared that plants which had flowered the year before were not in flower this year.

Also in 1989, fifty percent of the individuals in surveyed populations of A. molybdenus in Colorado were in flower. During that same year, populations of A. shultziorum in Wyoming only had good fruit production in occasional local areas within sites (Marriott 1990).

From these observations, it appears that flowering may be dependent on an interaction of the species' internal rhythms, and local temperature and moisture regimes.

2. POPULATION SIZE AND CONDITION: Populations of A. molybdenus are generally quite large (often greater than 10,000 stems). However, due to this species' ability to establish new ramets through rhizome extension, it is difficult to determine the number of genetic individuals in a population. Low flowering and fruiting frequencies probably limit population increases by way of seedling establishment.
3. REPRODUCTIVE BIOLOGY
 - a. TYPE OF REPRODUCTION: This species is a perennial. In 1989, Montana populations were observed to consist of approximately 90 to 95 percent vegetative ramets. As stated above, flowering and fruiting was restricted to small portions of the populations.

The establishment of new colonies through rhizome extension appears to be common to all

the populations studied (Montana, Wyoming, and Colorado). At all of the A. shultziorum sites, flowering and fruiting plants occur only in small localized areas within populations. It is possible that "populations" of plants at given sites are really collections of clones representing a single or a few genotypes that have colonized the area through vegetative propagation (Marriott 1990).

- b. POLLINATION BIOLOGY: Unknown.
- c. SEED DISPERSAL AND BIOLOGY: Fruits contain approximately 7-9 ovules. Mature fruits appear to drop from the plant before the sutures open. Although most fruits probably remain in the vicinity of the parent plant, the submembranous pods could be easily transported by the high winds that characterize alpine habitats.

F. TAXONOMIC STUDIES

Three methods were used to examine the taxonomic relationships between A. molybdenus (Montana and Colorado) and A. shultziorum (Wyoming): morphological comparisons, analysis of chloroplast DNA (cpDNA) fragmentation data (conducted by Dr. Matt Lavin, Montana State University), and electrophoretic analysis of enzyme variation (conducted by Dr. Greg Brown, University of Wyoming). The results of each of these studies are summarized below, followed by a brief discussion of their implications.

- a. MORPHOLOGICAL COMPARISONS: Specimens from populations in all three states were submitted to various herbaria, including Montana State University (MONT), New York Botanical Garden (NY), and the Rocky Mountain Herbarium, University of Wyoming (RM). Dr. Matt Lavin, Montana State University, summarized the morphological characteristics of plants from a limited number of herbarium sheets from each state; these are presented in Table 1, p. 13. The populations from Montana and Wyoming show similarities with respect to number of leaflets per leaf, number of flowers per raceme, the nature of the pod beak, and number of ovules per fruit. With respect to seed size and flower

TABLE 1. Morphological characteristics of A. molybdenus (Montana, Colorado) and A. shultziorum (Wyoming).* Summary provided by Dr. Matt Lavin, Montana State University. Similar values or characteristics among states are highlighted in bold print in shaded boxes.

	Colorado	Montana	Wyoming
Number of leaflets/leaf	17-25	11-13	9-15
Number of flowers/raceme	3-6	1-4	1-3
Nature of pod beak	short, stout	long, thin	long, thin
Number of ovules/ovary	6	7-9	8-9
Size of seeds (mm)	4-4.5	3.5-4.0	2.5-2.6
Flower color	purplish	purplish	whitish

* For this analysis, three herbarium sheets containing about five plants each were studied from the Montana and Colorado A. molybdenus populations. Five herbarium sheets with about five plants each were studied from the Wyoming A. shultziorum populations.

coloration, the Colorado and Montana populations are similar.

Additional morphological comparisons were summarized by Marriott (1990). The overall appearance of the Wyoming plants (A. shultziorum) is more open and loose than the Montana and Colorado plants (currently recognized as A. molybdenus), which are more compact and low-growing in habit. In the Wyoming plants, the flowers are consistently cream-colored, with pale purple striations on the banner, and a purple spot on the tip of the keel. The Colorado plants have petals that are creamy at the base and blue-purple at the tips. In Montana, the flowers are more extensively blue-purple. Fruit morphology among the states includes the most distinctive differences among the three regional units. Fruits from Colorado are the smallest, are shorter in relation to width, and have short beaks that contract abruptly from the main body of the legume. In Montana, the fruits are larger, longer relative to width, arcuate in shape, and taper gradually into a longer beak. Fruits from Wyoming appear to be intermediate in morphology. They are intermediate in size, but approach Montana material in relation of length to width. Beaks are similar to Montana material, but the legumes are little if at all arcuate.

Rupert Barneby, New York Botanical Garden, also examined specimens from all three states. In a letter to J.S. Shelly (10 January 1990), he stated that "(t)o my eye the material all looks increasingly alike, and I would now think that only one specific taxon is recognizable, possibly divided into varieties."

- b. cpDNA ANALYSIS: Chloroplast DNA is a circular strand of DNA contained in the chloroplasts (photosynthetic organelles) of plant cells. These circular molecules can be isolated from the cells, and differences in their genetic sequences can be studied by fragmenting them with restriction enzymes; these enzymes break the strands when they "find" certain DNA base pair sequences. The resulting fragments are then examined

electrophoretically (separated on electrically charged gels), and a "map" of the sequence of the fragments and their size is developed. These maps are then analyzed by computer, and diagrams of phylogenetic (evolutionary) relationships and the degree of cpDNA variation can be generated. The results of such studies for this Astragalus complex are presented in Figures 3 and 4, pp. 16-17. Three populations in each state were studied. The results indicate that the majority of the cpDNA genetic variation is partitioned between populations in different states, and that there is relatively little variation among populations within a single state (Fig. 3). The amount of variation among the states is very high (Lavin et al. 1990), approaching levels observed between full species. It was not clear from the analyses of the data whether the cpDNA among the three states is monophyletic (evolved from a common ancestor). The analysis in Figure 4 included one additional computer "step" (i.e., it was not the most parsimonious analysis), but it does suggest that the populations in the three states do share a common cpDNA ancestor. Most significantly, the results did reveal that at least the Montana (A. molybdenus) and Wyoming (A. shultziorum) populations are derived from a common ancestor.

- c. ELECTROPHORETIC ANALYSIS OF ENZYME VARIATION: This technique also involves a study of the genetic variation within and among populations, but the subjects of study are enzymes. Enzymes are proteins whose amino acid sequences are determined by the nuclear DNA (chromosomes); hence, differences between the enzymes, as detected by separating them on electrically charged gels, directly reflect genetic differences. In this study, five populations from Montana, four from Wyoming, and three from Colorado were examined. The results were generally inconclusive, but they do suggest that the populations are not highly divergent from one another in terms of chromosomal genetic variation. The sample size (number of individuals per population) was small, however, and an expanded study would be needed to obtain statistically significant

Figure 3. Chloroplast DNA genetic distances among populations of Astragalus molybdenus (Montana and Colorado) and A. shultziorum (Wyoming).

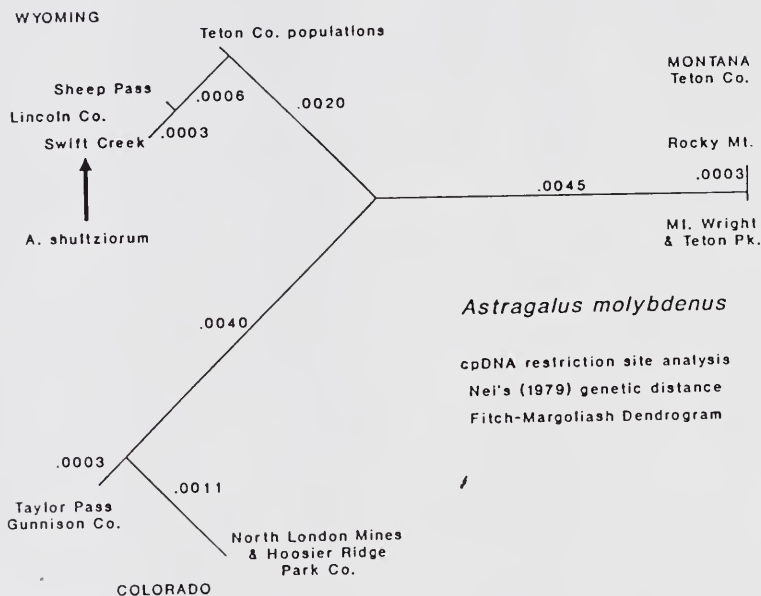
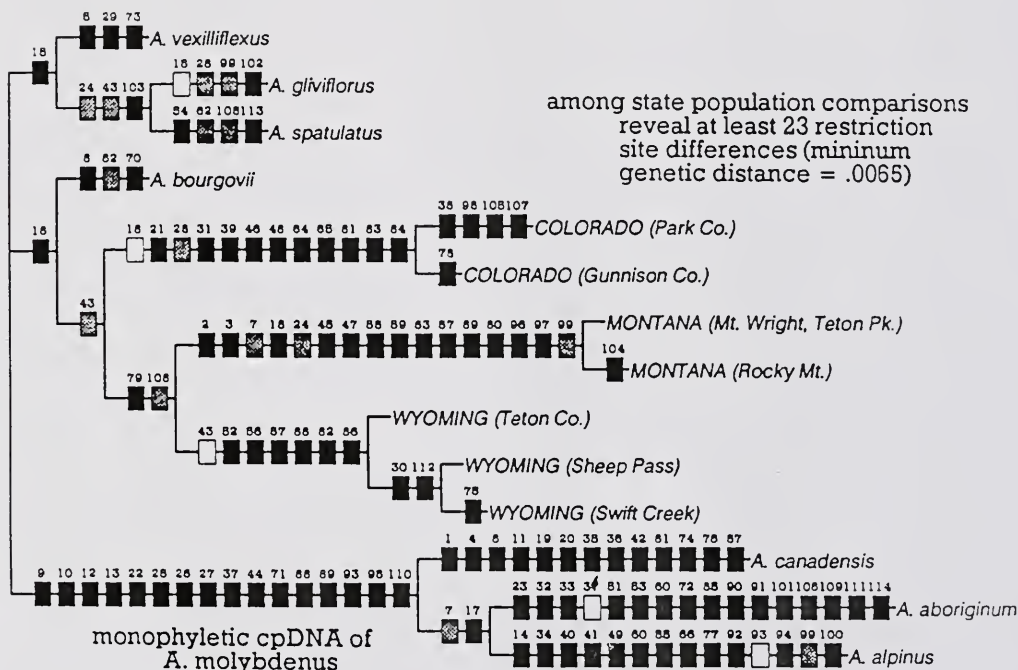


Figure 4. Computer analysis (cladogram) comparing chloroplast DNA restriction site differences within and among species of *Astragalus*, including populations of *A. molybdenus* ("COLORADO" and "MONTANA") and *A. shultziorum* ("WYOMING").



126 steps

CI = 114/126 = 0.904

measures of genetic variation (Brown 1990). Three of the seven enzymes studied did reveal patterns indicating that the Colorado and Montana populations are more similar to one another than either is to the Wyoming populations. The results also suggest the possibility of polyploidy (duplication of the full sets of chromosomes, resulting in higher chromosome numbers), again especially in the Colorado and Montana populations. Chromosome counts would be very useful in further clarifying the evolutionary relationships within the A. molybdenus-shultziorum complex.

- d. DISCUSSION: The results of each of these studies indicate that there has been some evolutionary divergence among the populations of Astragalus in all three states. This divergence is undoubtedly related to the large geographic distances separating them. The genetic studies do not align the populations in a similar pattern; while the cpDNA studies indicate a close relationship between the Montana and Wyoming populations, the enzyme studies suggest that the Colorado and Montana populations are most similar genetically. The cursory morphological studies do not reveal any major differences among the three states; however, the Montana and Wyoming populations do share certain features of fruit morphology. Thus, from a taxonomic viewpoint, it may be appropriate to recognize the populations from all three states as members of one widespread species; these could perhaps be distinguished as varieties, as suggested by Barneby. These populations are slowly diverging owing to the large present-day geographic gaps, and subsequent lack of interbreeding, between them. It is important to emphasize that the populations in all three states are largely clonal, and may represent only one or a few genotypes in each state (Lavin et al. 1990, Marriott 1990). The extensive vegetative reproduction, and relatively low observed rates of sexual reproduction, probably account for the low levels of genetic variation between populations within each state. These reproductive characteristics would also promote genetic differentiation between populations among the states (Lavin et al. 1990).

Final resolution of the taxonomy of this complex is in progress, and will be published in the scientific literature. The results will be provided to the U.S. Forest Service upon completion.

G. POPULATION ECOLOGY

1. BIOLOGICAL INTERACTIONS

- a. COMPETITION: Astragalus molybdenus apparently tolerates competition, as it was often found in association with large Dryas octopetala mats. In Montana, total ocular vegetation cover (including A. molybdenus plants) was often 100 percent. However, as a member of alpine communities, or open subalpine communities, this species may not be shade tolerant.
- b. HERBIVORY: No evidence of herbivory was observed in the field.

H. LAND OWNERSHIP

1. All of the known locations for A. molybdenus in Montana are on the Lewis and Clark National Forest in the Sawtooth Range. The exact locations are provided in Section VI, pp. 25-37.

IV. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

A. THREATS TO CURRENTLY KNOWN POPULATIONS:

1. GRAZING: No threats. It is likely that these habitats are grazed intermittently by wild goats or sheep, but this probably does not threaten the plant populations.
2. MINING: All of the locations for A. molybdenus are at high elevations in the Sawtooth Range, on the Lewis and Clark National Forest. Surveys for this species should be initiated if oil drilling or mining projects are proposed in high elevation habitats with potential for supporting this species.
3. TIMBER HARVESTING: No threats.
4. WEED CONTROL ACTIVITIES: Currently no threats.

- B. MANAGEMENT PRACTICES AND RESPONSE: There are currently no management practices that threaten the habitat of A. molybdenus, nor any known means of enhancing populations.
- C. RECOMMENDATIONS FOR MAINTAINING VIABLE POPULATIONS: In Montana, populations appear to be self-sustaining, and most are in areas that receive little human impact. Several areas, including Our Lake (002), are popular destinations for hikers and campers. It may be appropriate at some point to provide protection for the populations, through special site designations and public education.
1. CONSERVATION BIOLOGY: As discussed in the section regarding the taxonomic studies, there has been some morphological and genetic divergence among the populations in Montana, Wyoming, and Colorado. Thus, even if A. molybdenus and A. shultziorum are ultimately combined into one varietally segregated species, it will be very important to ensure the long-term maintenance of populations in all three states. In this way, the entire range of genetic variation in the complex will be retained. This will allow for a greater chance of successful adaptation in the face of possible climatic changes or other ecological shifts. In addition, maintenance of as many populations as possible in each state will retain the intrastate genetic variation that is starting to appear as evidenced by the cpDNA data. Lastly, the current distribution of the A. molybdenus-shultziorum complex is biogeographically unique, and maintenance of populations throughout its range will allow for future scientific interpretation of its fragmented occurrence pattern.
- D. STATUS RECOMMENDATION AND FURTHER ASSESSMENT NEEDS: It is recommended that this species be maintained on the U.S. Forest Service, Region 1, sensitive plant species list. Although most of the populations do occur in remote areas that receive limited human impact, the known sites are all within a 10 mile area. It is also recommended that further surveys be conducted, to the north and south of the known populations in Montana. This would help to define the full range of this species in the Sawtooth Range. Establishment of a demographic monitoring study would reveal important life history characteristics, such as fecundity and life-span of individuals or clones.

E. SUMMARY

In 1989, the Lewis and Clark National Forest and the Montana Natural Heritage Program entered a Challenge Cost-share agreement. Under the agreement, the Montana Natural Heritage Program conducted field surveys to determine the distribution of Astragalus molybdenus populations on Forest lands. In addition, plant material was collected for morphologic and molecular systematic studies to compare these populations to Colorado populations, and to populations of Astragalus shultziorum from western Wyoming.

Survey efforts revealed seven new populations of A. molybdenus in the Sawtooth Range, Teton County, Montana. All of these populations occur within 10 miles of the original collection site on Mt. Wright. This brings the total number of known populations in Montana to eight. All of the populations were quite large, although it appears that populations expand by cloning through rhizome extension, rather than by establishment of new plants from seed. At least in 1989, sexual reproduction was limited to small portions of most populations (the exception was at Our Lake (002)). In 1990, flowering and fruiting again appeared to be fairly extensive at Our Lake (002).

Additional surveys could reveal more populations to the north or south of the known populations, in areas where calcareous soils occur in alpine or very open subalpine (7,000 to 8,000 ft. in elevation) habitats.

The results of the taxonomic studies indicate that there has been some evolutionary divergence among the populations of Astragalus in all three states. The genetic studies do not align the populations in a similar pattern; while the cpDNA studies indicate a close relationship between the Montana and Wyoming populations, the enzyme studies suggest that the Colorado and Montana populations are most similar genetically. The cursory morphological studies do not reveal any major differences among the three states; however, the Montana and Wyoming populations do share certain features of fruit morphology not found in Colorado plants. Thus, from a taxonomic viewpoint, it may be appropriate to recognize the populations from all three states as members of one widespread species; these could perhaps be distinguished as varieties, as suggested by Barneby. It is important to emphasize that the populations in all three states are largely clonal, and may represent only one or a few genotypes in each state (Lavin et al. 1990, Marriott 1990).

Final resolution of the taxonomy of this complex is in progress, and will be published in the scientific literature. The results will be provided to the U.S. Forest Service upon completion.

V. LITERATURE CITED

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VI. ELEMENT OCCURRENCE PRINT-OUTS AND MAPS

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 001

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: MOUNT WRIGHT
EO rank: A
EO rank comments: RELATIVELY LARGE POPULATIONS,
UNDISTURBED ALPINE AREAS.

County: TETON

USGS quadrangle: MOUNT WRIGHT

Township-range: 026N 010W Section: 25, S2; Section: 36, NW4

Survey date:	1989-08-08	Elevation:	8100
First observation:	1982	Slope/aspect:	0-35% / N, E, NE, LEVEL
Last observation:	1989-08-29	Size (acres):	25

Location:

SAWTOOTH RANGE, EAST AND NORTHEAST SLOPES OF MOUNT WRIGHT,
NORTH FORK TETON RIVER DRAINAGE.

Element occurrence data:

SIX SUBPOPULATIONS; EXTENSIVE VEGETATIVE SPREADING, BUT VERY FEW
PLANTS FLOWERING AND FRUITING; POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:

ALPINE AND SUBALPINE AREAS, LIMESTONE SUBSTRATES; WITH DRYAS
OCTOPETALA, OXYTROPIS PODOCARPA, BUPLEURUM AMERICANUM, SMELOWSKIA
CALYCINA, SIBBALDIA PROCUMBENS.

Land owner/manager:

BOB MARSHALL WILDERNESS AREA
LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

VOUCHERS - SHELLY, J.S. (1592), L. SCHASSBERGER, A. EVENDEN, AND J.
PIERCE, RM, 1989; SHELLY, J.S. (1593) AND A. EVENDEN, MONT, 1989.

Information source:

SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 002

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: OUR LAKE
EO rank: A
EO rank comments:

County: TETON

USGS quadrangle: OUR LAKE

Township-range: 024N 009W Section: 18, NE4SW4

Survey date: 1989-08-09	Elevation: 8120
First observation: 1989	Slope/aspect: 0-35% / NORTH, WEST,
LEVEL	
Last observation: 1990-07-28	Size (acres): 25

Location:

CA. 33 MILES WEST OF CHOTEAU. FROM THE WEST END OF F.S. ROAD #109, TRAVEL 2 MILES SSW TO OUR LAKE; SITE IS IN BASIN ABOVE AND SOUTH OF THE LAKE.

Element occurrence data:

HEAVILY IN FRUIT (1989). ONE LARGE POPULATION AND ONE SMALL POPULATION; NUMEROUS SCATTERED INDIVIDUALS. MANY PLANTS IN FLOWER (1990).

General site description:

IN TURFY, MOIST LIMESTONE SOIL, WITH DRYAS OCTOPETALA, CERASTIUM ARVENSE, SMELOWSKIA CALYCINA, ERIGERON COMPOSITUS, AND POLEMONIUM PULCHERRIMUM.

Land owner/manager:

LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

VOUCHER - SCHASSBERGER, L.A. (343) AND J. PIERCE, NY, 1989.

Information source:

SCHASSBERGER, L.A. 1989. FIELD SURVEYS OF THE FRONT RANGE MOUNTAINS, 7-10 AND 21-23 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 003

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: TETON SKI AREA PEAK
EO rank: A
EO rank comments: REMOTE LOCATION.

County: TETON

USGS quadrangle: MOUNT WRIGHT

Township-range: 025N 010W Section: 12, SE4; Section: 13, NW4

Survey date: 1989-08-08	Elevation: 7960
First observation: 1989	Slope/aspect: 0-35% / NW, SOUTH, EAST
Last observation: 1989-08-08	Size (acres): 15

Location:

CA. 34 MILES WEST OF CHOTEAU, ON WEST SIDE OF PEAK ABOVE TETON PASS
SKI AREA, AND SOUTHWEST ALONG THE RIDGE OF MOUNT LOCKHART.

Element occurrence data:

TWO LARGE SUBPOPULATIONS.

General site description:

IN MOIST, TURFY LIMESTONE SOIL, WITH DRYAS OCTOPETALA, SMELOWSKIA
CALYCINA, OXYTROPIS VISCIDA, ANDROSACE CHAMAEJASME, SAXIFRAGA
BRONCHIALIS, HEDYSARUM SULPHURESCENS, ASTRAGALUS ALPINUS, AND ERIGERON
LACKSCHEWITZII.

Land owner/manager:

LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

VOUCHERS - SCHAASBERGER, L.A. (337) AND J. PIERCE, NY, 1989; (338),
MONT.

Information source:

SCHAASBERGER, L.A. 1989. FIELD SURVEYS OF THE FRONT RANGE MOUNTAINS,
7-10 AND 21-23 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 004

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: ROCKY MOUNTAIN-WEST
EO rank: A
EO rank comments: LARGE COLONIES, IN UNDISTURBED ALPINE
AREAS.

County: TETON

USGS quadrangle: OUR LAKE

Township-range: 024N 009W Section: 19, S2; Section: 30, N2

Survey date: 1989-08-10	Elevation: 8000
First observation: 1989	Slope/aspect: 0-35% / N,NW,W
Last observation: 1989-08-10	Size (acres): 20

Location:

SAWTOOTH RANGE, WEST AND NW SLOPES OF ROCKY MOUNTAIN PEAK, 0.3-0.75 AIR
MI. SOUTH TO SSE OF HEADQUARTERS CREEK PASS.

Element occurrence data:

FIVE SUBPOPULATIONS OBSERVED, SOME SPREADING EXTENSIVELY BY VEGETATIVE
REPRODUCTION; POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:

ALPINE HABITATS, 7640 - 9200', ALMOST ALWAYS IN DRYAS OCTOPETALA MATS
BUT OCCASIONALLY IN SCREE, ON LIMESTONE SUBSTRATE; WITH SMELOWSKIA
CALYCINA, ANTENNARIA AROMATICA, ANDROSACE LEHMANNIANA, SAXIFRAGA
BRONCHIALIS, ERIGERON LACKSCHEWITZII, SALIX NIVALIS, ZIGADENUS
ELEGANS.

Land owner/manager:

BOB MARSHALL WILDERNESS AREA
LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

VOUCHERS-SHELLY, J.S. (1602) AND L.A. SCHASSBERGER, NY, MONT, 1989.

Information source:

SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 005

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: ROCKY MOUNTAIN-NORTHEAST
EO rank: A
EO rank comments: LARGE COLONIES, IN UNDISTURBED ALPINE
AND SUBALPINE AREAS.

County: TETON

USGS quadrangle: OUR LAKE

Township-range: 024N 009W Section: 20, SW4

Survey date: 1989-08-10	Elevation: 8040
First observation: 1989	Slope/aspect: 0-35% / N, NW
Last observation: 1989-08-30	Size (acres): 20

Location:

SAWTOOTH RANGE, NORTH AND NE SLOPES OF ROCKY MOUNTAIN PEAK, 0.4-0.85 AIR
MILES EAST TO SE OF HEADQUARTERS CREEK PASS.

Element occurrence data:

THREE SUBPOPULATIONS OBSERVED, SOME SPREADING BY VEGETATIVE
REPRODUCTION; POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:

ALPINE AND SUBALPINE AREAS, 7440-8670', OFTEN IN DRYAS OCTOPETALA MATS
BUT OCCASIONALLY IN SCREE, ON LIMESTONE SUBSTRATE.

Land owner/manager:

BOB MARSHALL WILDERNESS AREA
LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

SIGHT RECORD, VOUCHER COLLECTED FROM WEST SIDE OF ROCKY MOUNTAIN
(004), SHELLY (1602) AND SCHASSBERGER; SEEDS FOR SYSTEMATIC STUDY
COLLECTED FROM NORTHERN SUBPOPULATION; BORDERS WATERSHED 10030104.

Information source:

SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 006

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: ROUTE CREEK PASS
EO rank: B
EO rank comments: LARGE COLONIES, BUT SITE IS TRAVERSED BY
A HIKING TRAIL.

County: TETON

USGS quadrangle: OUR LAKE

Township-range: 025N 010W Section: 36, SE4

Survey date: 1989-08-22 Elevation: 7263
First observation: 1989 Slope/aspect: 0-15% / E, NE, NW,
LEVEL
Last observation: 1989-08-23 Size (acres): 2

Location:
SAWTOOTH RANGE, ROUTE CREEK PASS, ON DIVIDE BETWEEN MIDDLE
FORK NORTH FORK TETON RIVER AND ROUTE CREEK, LEWIS & CLARK N.F. TRAIL
#108.

Element occurrence data:
ONE POPULATION; EXTENSIVE VEGETATIVE SPREADING, BUT LITTLE FLOWERING
AND FRUITING; SITE IS TRAVERSED BY A MODERATELY-USED PACK TRAIL;
POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:
SUBALPINE AREA, ON GRAVELLY LIMESTONE SUBSTRATE; WITH DRYAS
OCTOPETALA, POTENTILLA FRUTICOSA, JUNIPERUS COMMUNIS, ZIGADENUS
ELEGANS, ANTENNARIA AROMATICA, ANDROSACE LEHMANNIANA, SMELOWSKIA
CALYCINA, HEDYSARUM SULPHURESCENS, CAMPANULA ROTUNDIFOLIA, DOUGLASIA
MONTANA, AQUILEGIA JONESII.

Land owner/manager:
BOB MARSHALL WILDERNESS AREA
LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:
VOUCHERS-SCHASSBERGER, L.A. (353) AND J.S. SHELLY, NY, MONT, 1989;
BORDERS WATERSHED 10030104.

Information source:
SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 007

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: TETON PEAK
EO rank: A
EO rank comments: LARGE COLONIES, IN UNDISTURBED REMOTE
HABITAT.

County: TETON

USGS quadrangle: MOUNT WRIGHT

Township-range: 025N 010W Section: 36, NE4

Survey date:	1989-08-22	Elevation:	7600
First observation:	1989	Slope/aspect:	3-35% / N, E, NE
Last observation:	1989-08-22	Size (acres):	5

Location:

SAWTOOTH RANGE, 0.35-0.85 AIR MI. SE OF TETON PEAK, 0.75
AIR MI. NORTH TO NE OF ROUTE CREEK PASS, MIDDLE FORK NORTH FORK TETON
RIVER DRAINAGE.

Element occurrence data:

THREE COLONIES; EXTENSIVE VEGETATIVE SPREADING, BUT LITTLE FLOWERING
AND FRUITING; POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:

ALPINE AND SUBALPINE TURF, LIMESTONE GRAVEL AND SCREE; OFTEN IN DRYAS
OCTOPETALA MATS, WITH BUPLEURUM AMERICANUM, ASTRAGALUS BOURGOVII,
HEDYSARUM SULPHURESCENS, POTENTILLA FRUTICOSA, ANDROSACE LEHMANNIANA,
POLEMONIUM PULCHERRIMUM, PEDICULARIS CONTORTA, ZIGADENUS ELEGANS,
GENTIANA CALYCOSA, ACHILLEA MILLEFOLIUM, PENSTEMON PROCERUS.

Land owner/manager:

LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

SIGHT RECORD, VOUCHER COLLECTED AT NEARBY ROUTE CREEK PASS SITE
(SCHASSBERGER (353) AND SHELLY).

Information source:

SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.

ELEMENT OCCURRENCE RECORD
Astragalus molybdenus (Leadville milk-vetch)

Occurrence number: 008

Global rank: G3 Forest Service status: SENSITIVE LIST
State rank: S1 USFWS Status: NONE

Survey site name: OLD BALDY
EO rank: A
EO rank comments: LARGE COLONIES IN UNDISTURBED ALPINE
AREA.

County: TETON

USGS quadrangle: OUR LAKE

Township-range: 024N 010W Section: 01, E2

Survey date:	1989-08-23	Elevation:	7420
First observation:	1989	Slope/aspect:	8-35% / N, NW
Last observation:	1989-08-23	Size (acres):	10

Location:

SAWTOOTH RANGE, NORTH SLOPES OF OLD BALDY, CENTERED 0.65
AIR MI. NORTH OF SUMMIT SADDLE, MIDDLE FORK NORTH FORK TETON RIVER.

Element occurrence data:

THREE COLONIES; EXTENSIVE VEGETATIVE SPREADING, BUT LITTLE FLOWERING
AND FRUITING; POPULATION SIZE DIFFICULT TO ESTIMATE.

General site description:

ALPINE SCREE AND DRYAS OCTOPETALA MATS, LIMESTONE SUBSTRATE; WITH
CLAYTONIA MEGARHIZA, SMELOWSKIA CALYCINA, ANDROSACE LEHMANNIANA,
HEDYSARUM SULPHURESCENS, KOBRESIA BELLARDII, ANTENNARIA AROMATICA,
ARCTOSTAPHYLOS UVA-URSI, SAXIFRAGA BRONCHIALIS, DOUGLASIA MONTANA.

Land owner/manager:

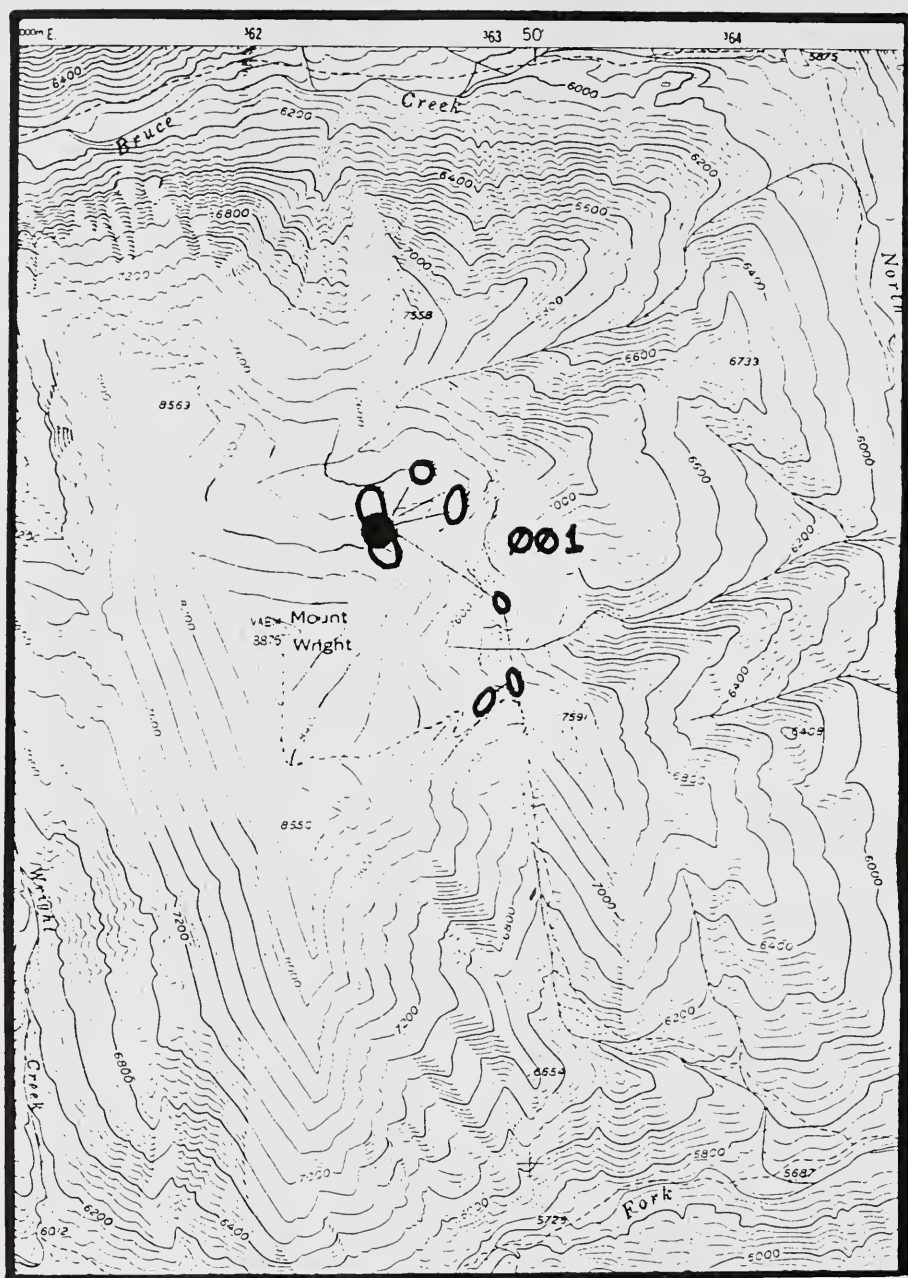
LEWIS & CLARK NATIONAL FOREST, ROCKY MOUNTAIN RANGER DISTRICT

Comments:

VOUCHER-SHELLY, J.S. (1609) & L.A. SCHASSBERGER, NY, 1989.

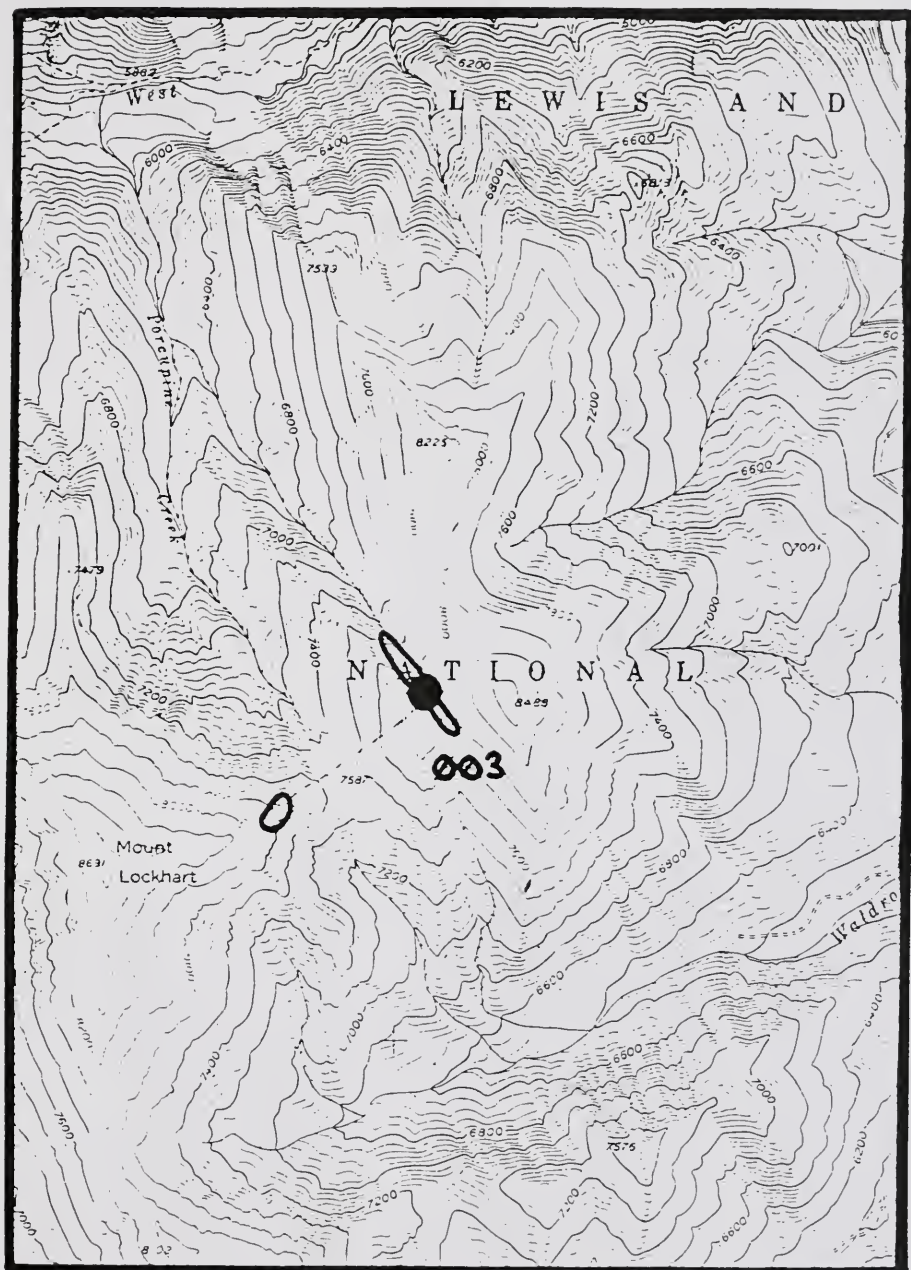
Information source:

SHELLY, J.S. 1989. FIELD SURVEYS IN TETON COUNTY, 7-10, 21-23, AND
28-30 AUGUST.



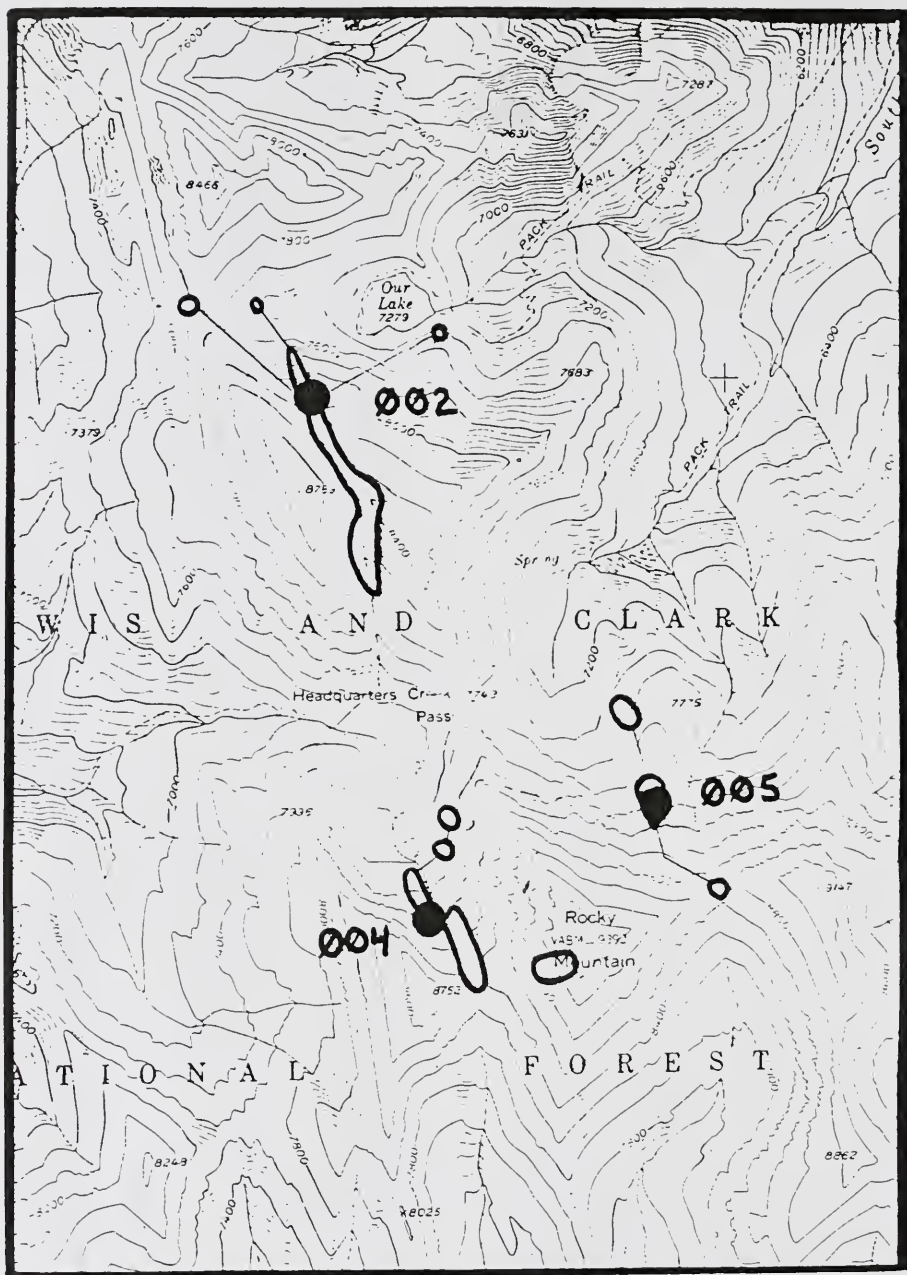
U.S.G.S. Mount Wright Quadrangle (7.5')

Astragalus molybdenus



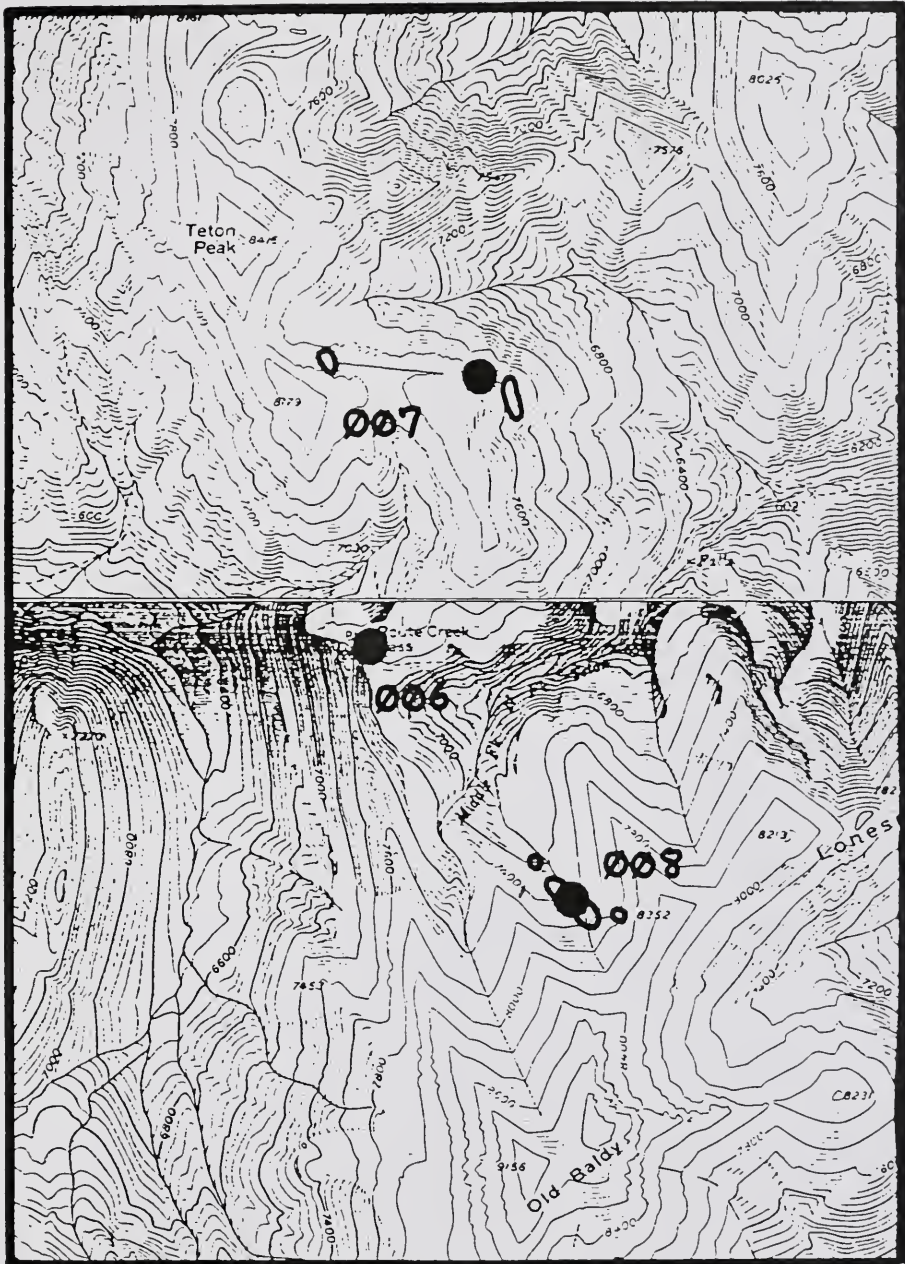
U.S.G.S. Mount Wright Quadrangle (7.5')

Astragalus molybdenus



U.S.G.S. Our Lake Quadrangle (7.5')

Astragalus molybdenus



U.S.G.S. Mount Wright Quadrangle (7.5') - TOP
 U.S.G.S. Our Lake Quadrangle (7.5') - BOTTOM

Astragalus molybdenus

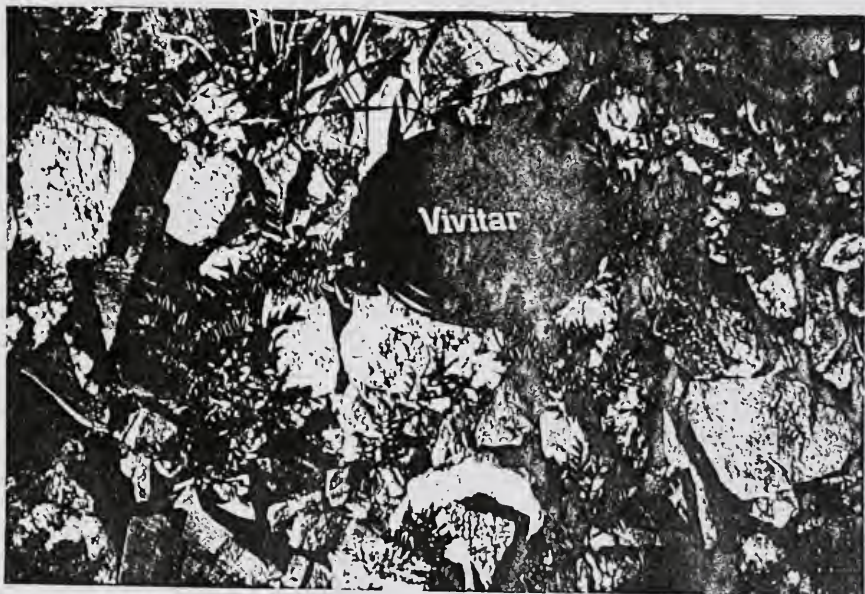
VII. PHOTOGRAPHS



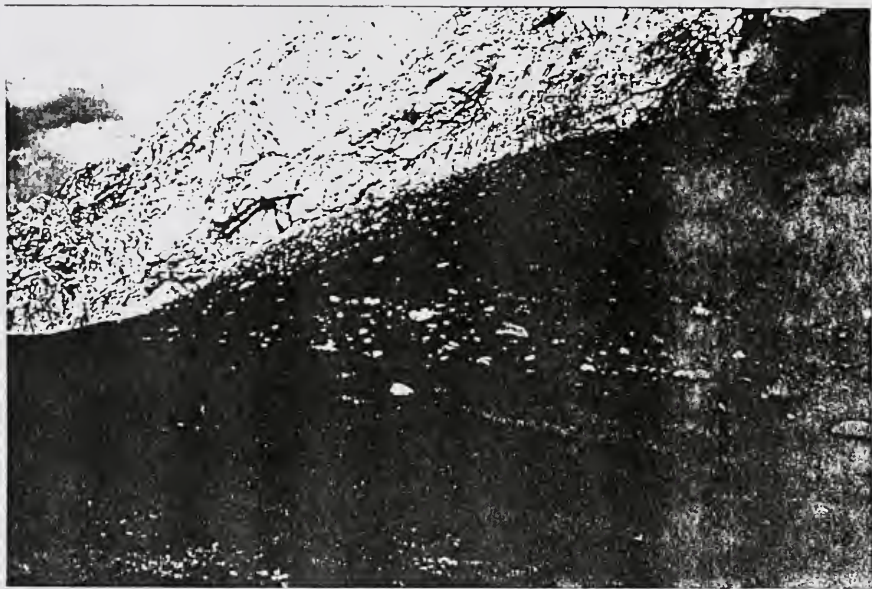
- A. Astragalus molybdenus - plant with flowers and early fruits (Our Lake (002) site).



B. Astragalus molybdenus - plant in fruit (Our Lake (002) site).



C. Astragalus molybdenus - habit.



D. Astragalus molybdenus - habitat (Teton Ski Area Peak (003) site).



E. Astragalus molybdenus - habitat; note areas of stabilized scree.



F. Astragalus molybdenus - habitat; note areas of stabilized scree.



G. Astragalus molybdenus - habitat (Teton Ski Area Peak
(003) site).

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